

The Benefit of Ground Truth Data to Semantic Conformance Testing of Fingerprint Minutia Encoding

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Introduction

- What is „Ground Truth Data“ for Fingerprint Minutia Encoding?
- a winter prespective....

Introduction



This is Africa
and we can consider it as a
~~biometric characteristic~~
geographic characteristic.
It is
a continental part
of our ~~body~~ globe.

Introduction



and
this is the Sahara,
which is
a significant part of Africa
as it is the world's largest
hot desert.

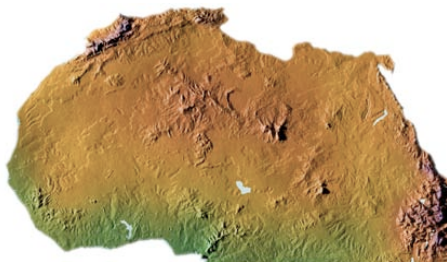
Introduction



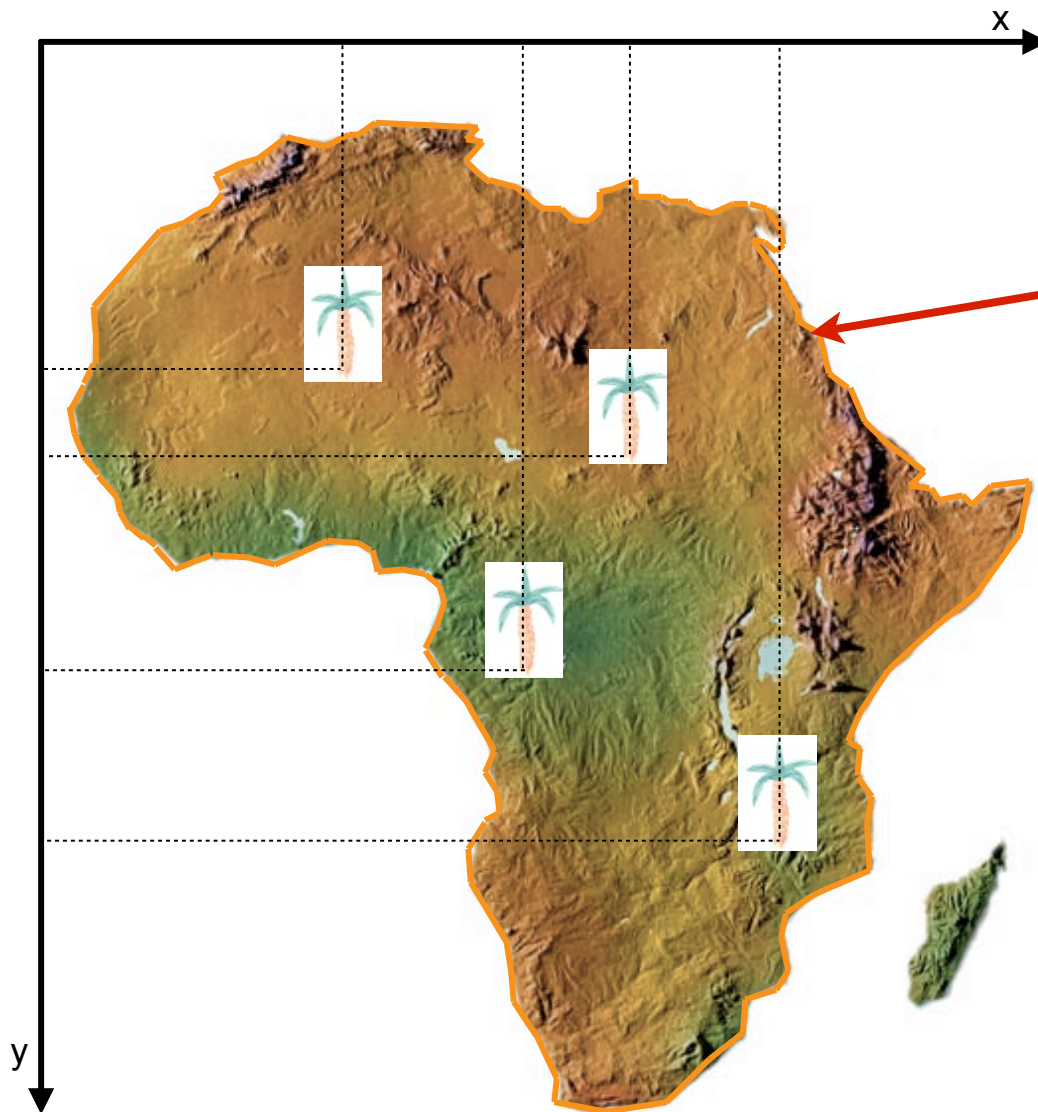
and
this is a palm tree
there are many palm trees
in the Sahara.



They serve as **landmarks**
and we like to see them
close to some water (oasis).



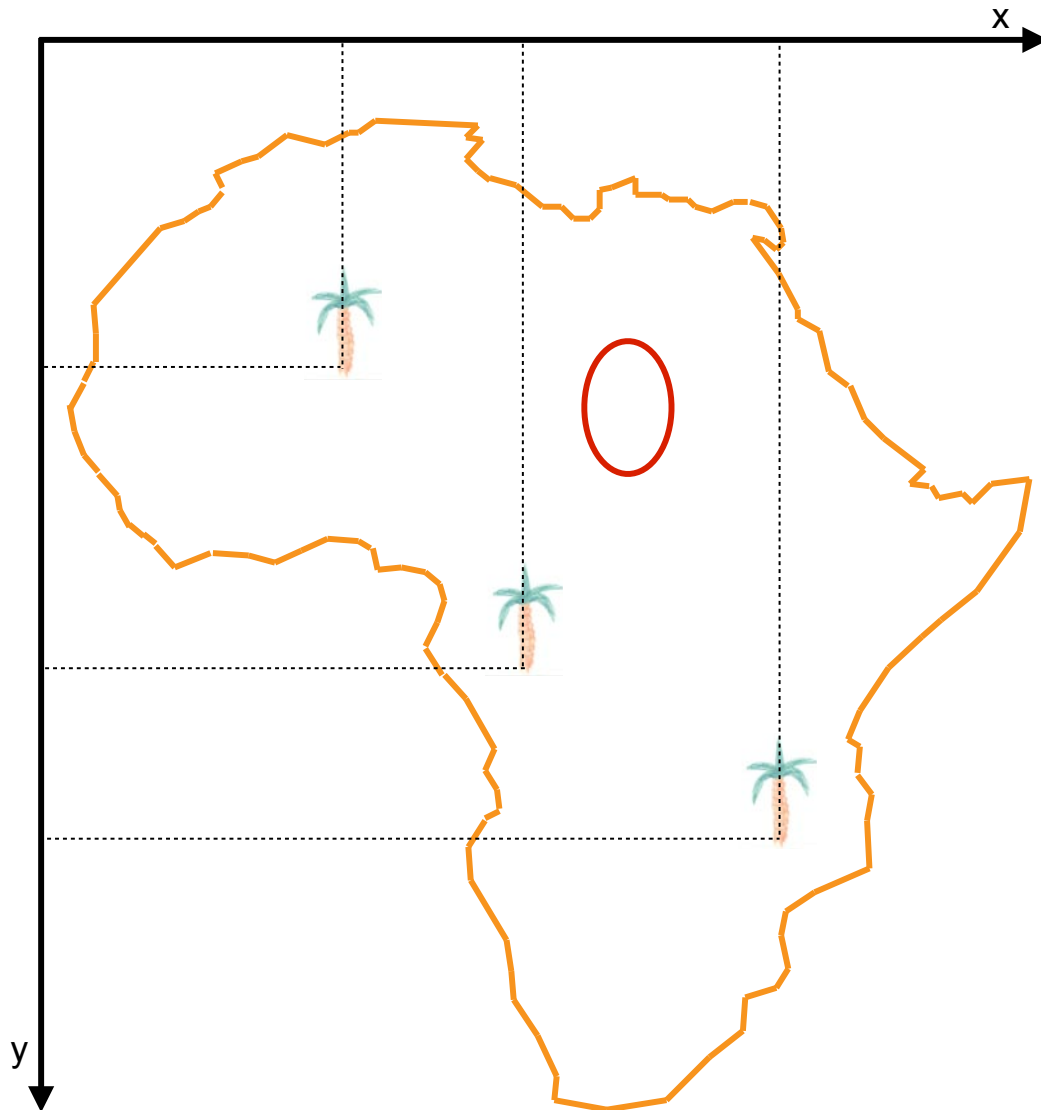
Introduction



and
this is a **representation**
of the geographic characteristic
that has been generated
from the geographic sample.
The representation contains
features which encode
the locations of the landmarks.



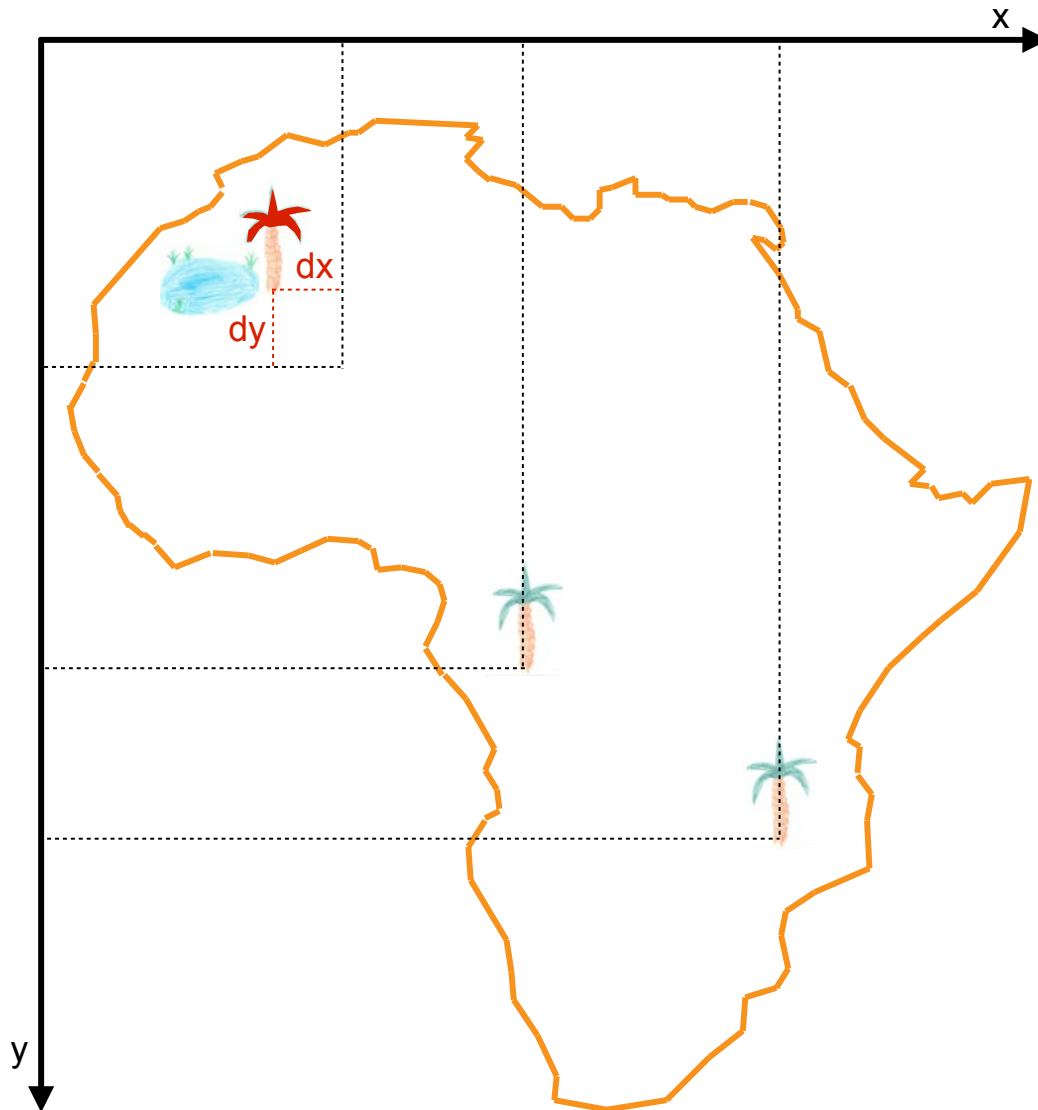
Introduction



unfortunately
the Sahara is the source
of **sandstorms** that causes
regionally a bad visibility.
In consequence
the **feature extractor**
will **not** detect the
poorly visible **landmark**



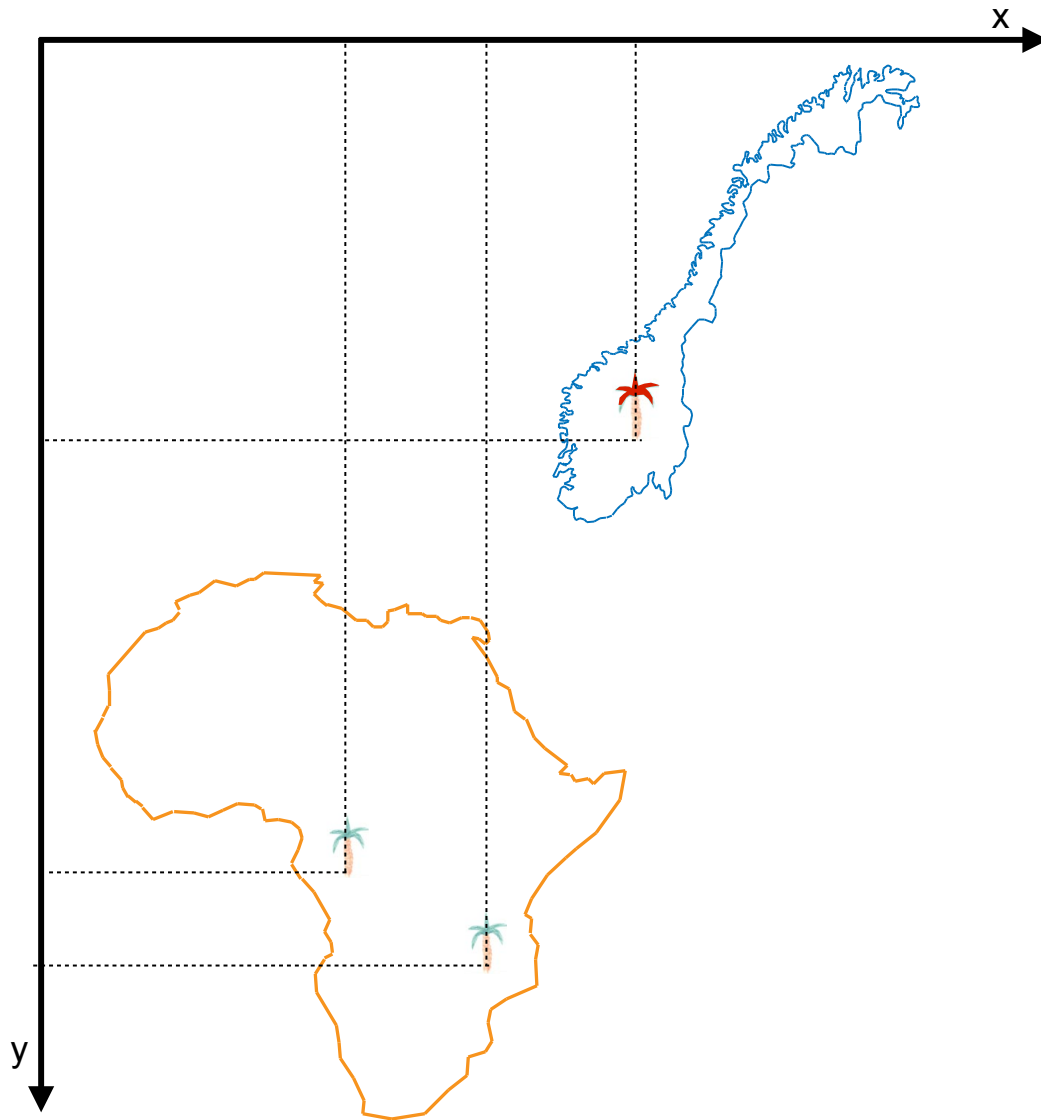
Introduction



a **second** problem
is a **fata morgana**
that causes the
feature extractor to detect
the **feature** (with an oasis?)
at a dis-located position.
Thus the encoded feature
does **not** represent the **landmark**



Introduction



a **third** problem
could be the **globalisation**.
If the **feature extractor** seeks
for landmarks **out of area**
he may detect falsely a **feature**
at a position, where
you can find in reality rather
other biological entities (elks)

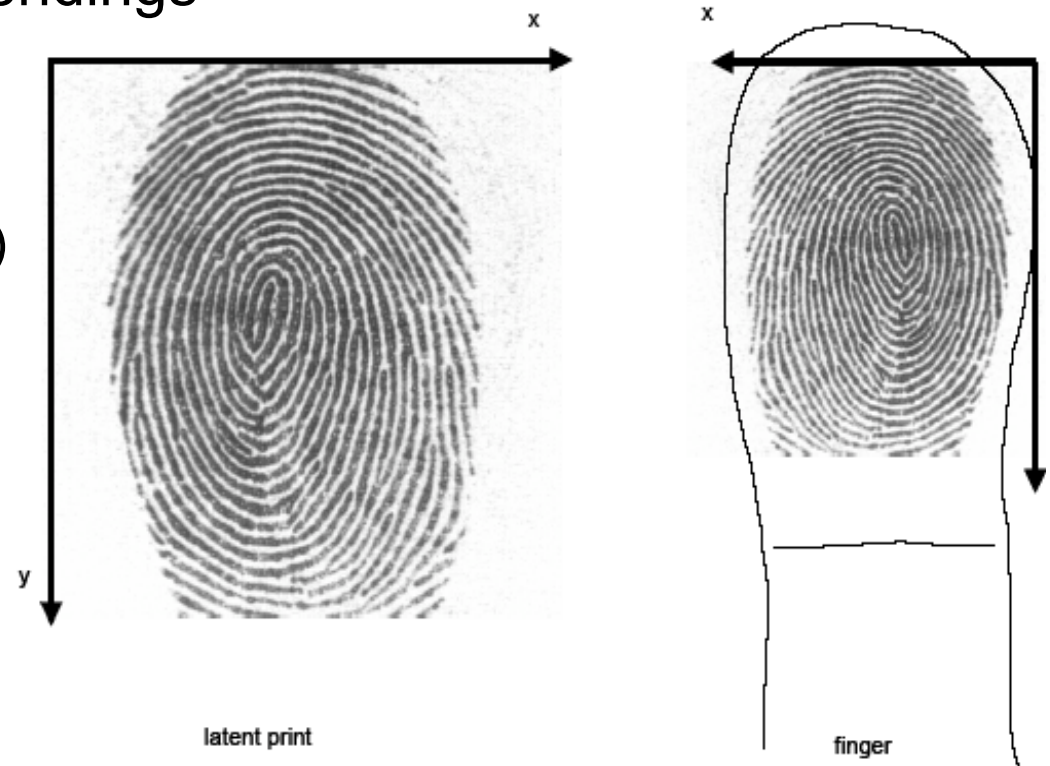


Properties of Finger Minutiae Detectors

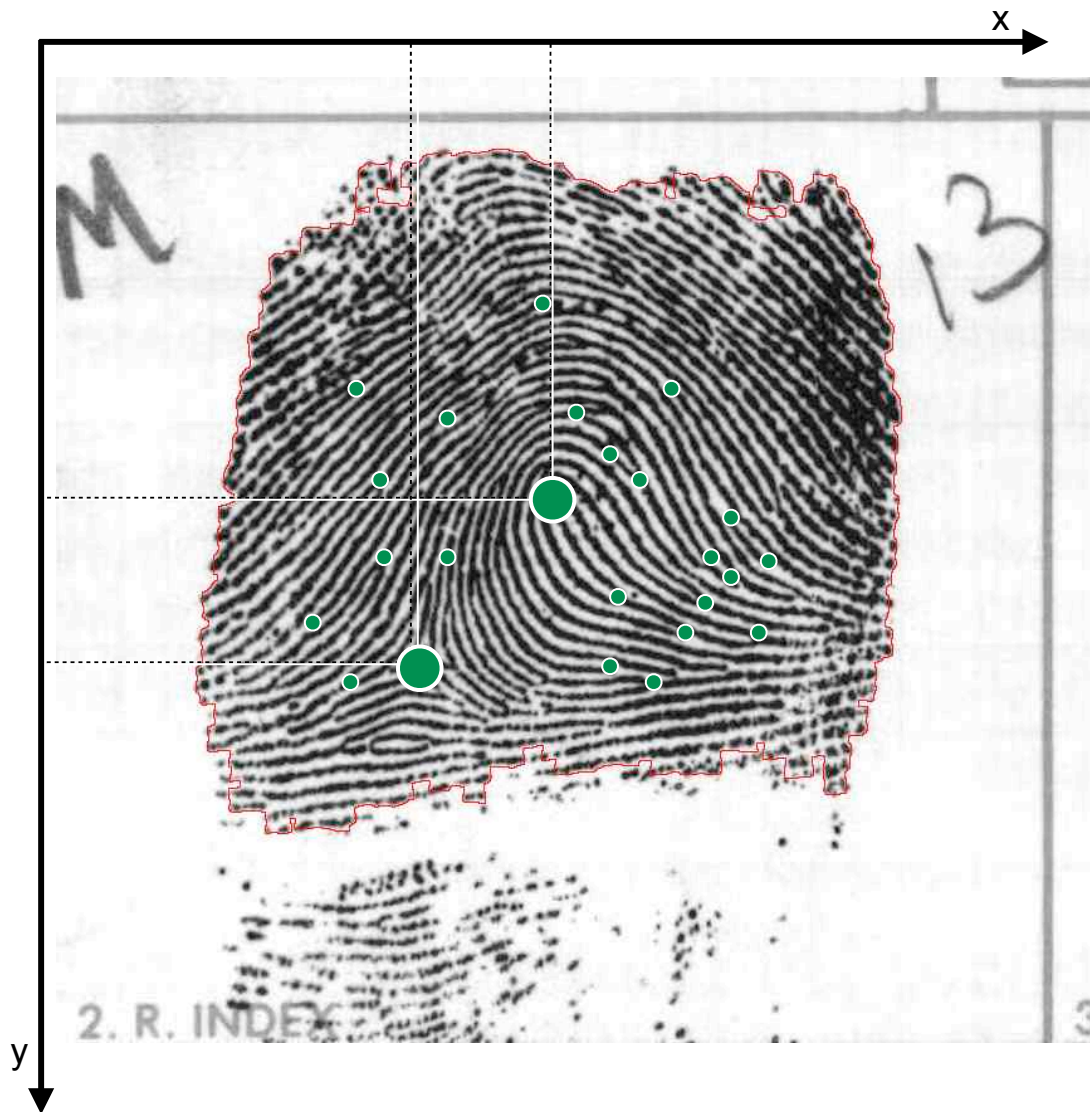
Representation in Minutia Format

ISO/IEC 19794-2: Biometric data interchange formats - Part 2: Finger minutiae data

- Ridges and valleys, core and delta
- Ridge bifurcation and ridge endings
 - ▶ finger minutiae
- Encoded main features
 - ▶ Minutia point (coordinates x,y)
 - ▶ Minutia direction (angle θ)
 - ▶ Minutia type
- Other features are e.g.
 - ▶ quality



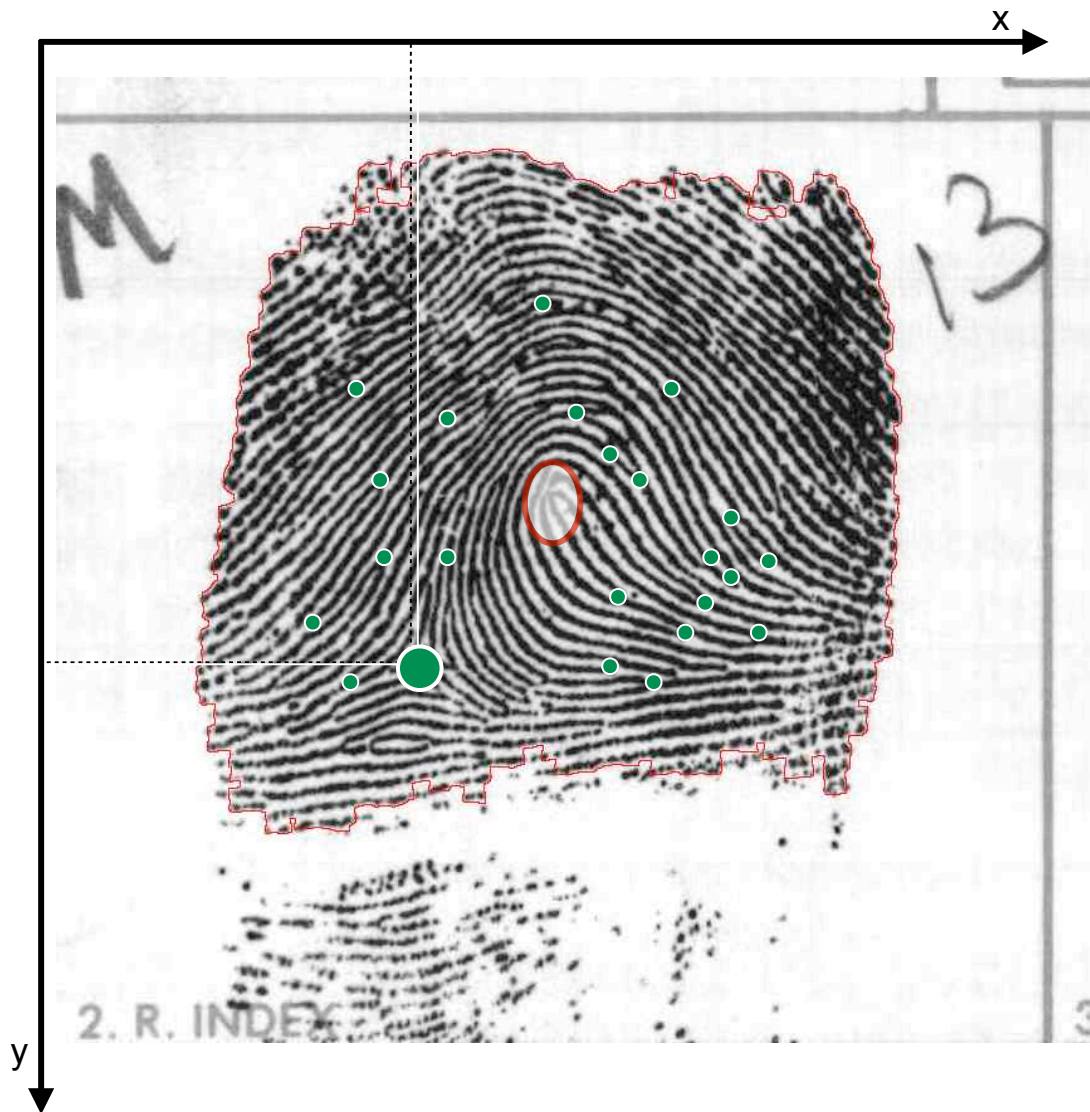
Encoding the Minutia Format



When a ISO 19794-2 compliant **feature extractor** processes a biometric fingerprint image he generates a minutiae **template**.

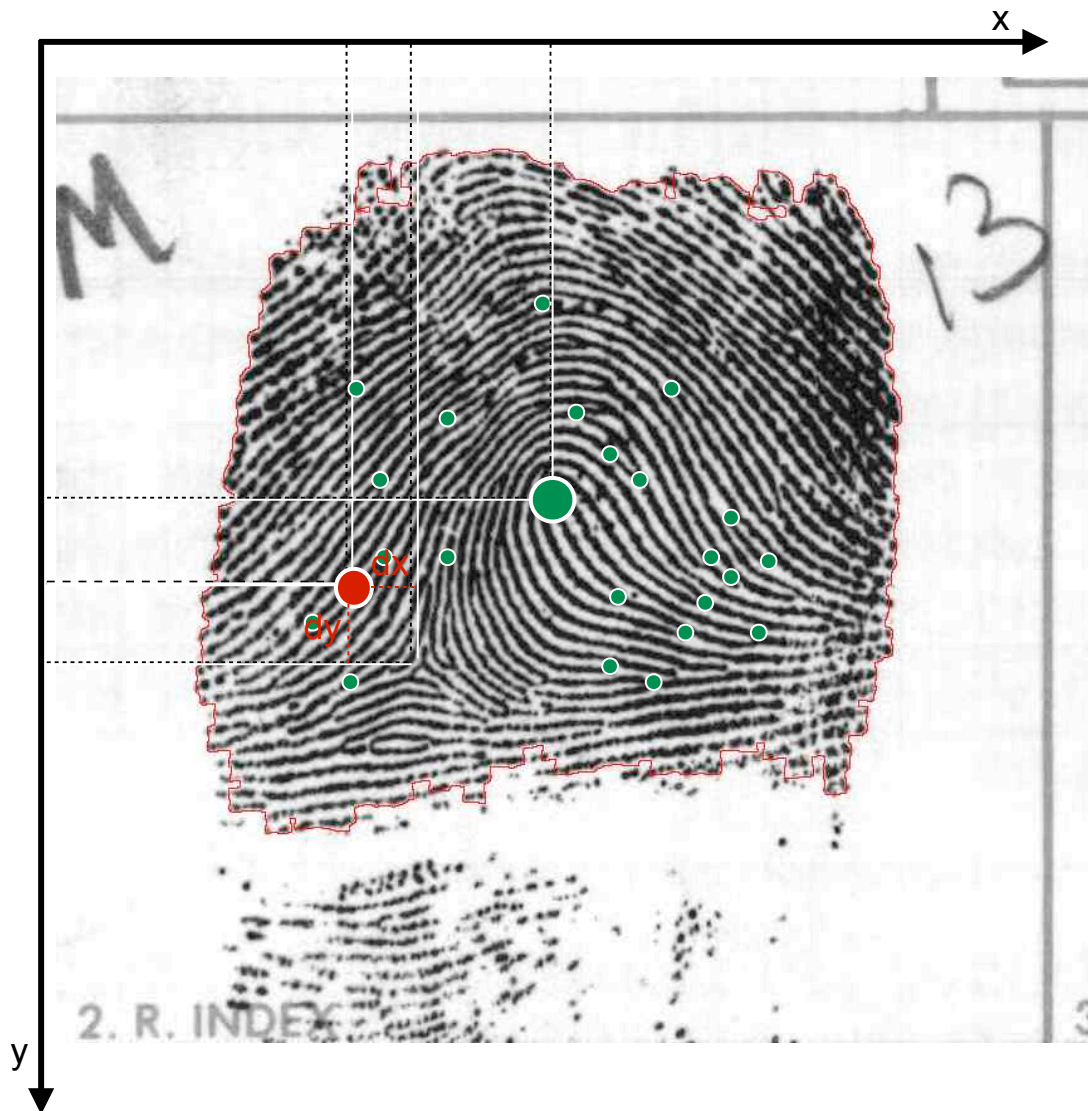
We will find the location for the core and for the delta and for many other minutiae.

Deficiencies of the Minutia Encoder



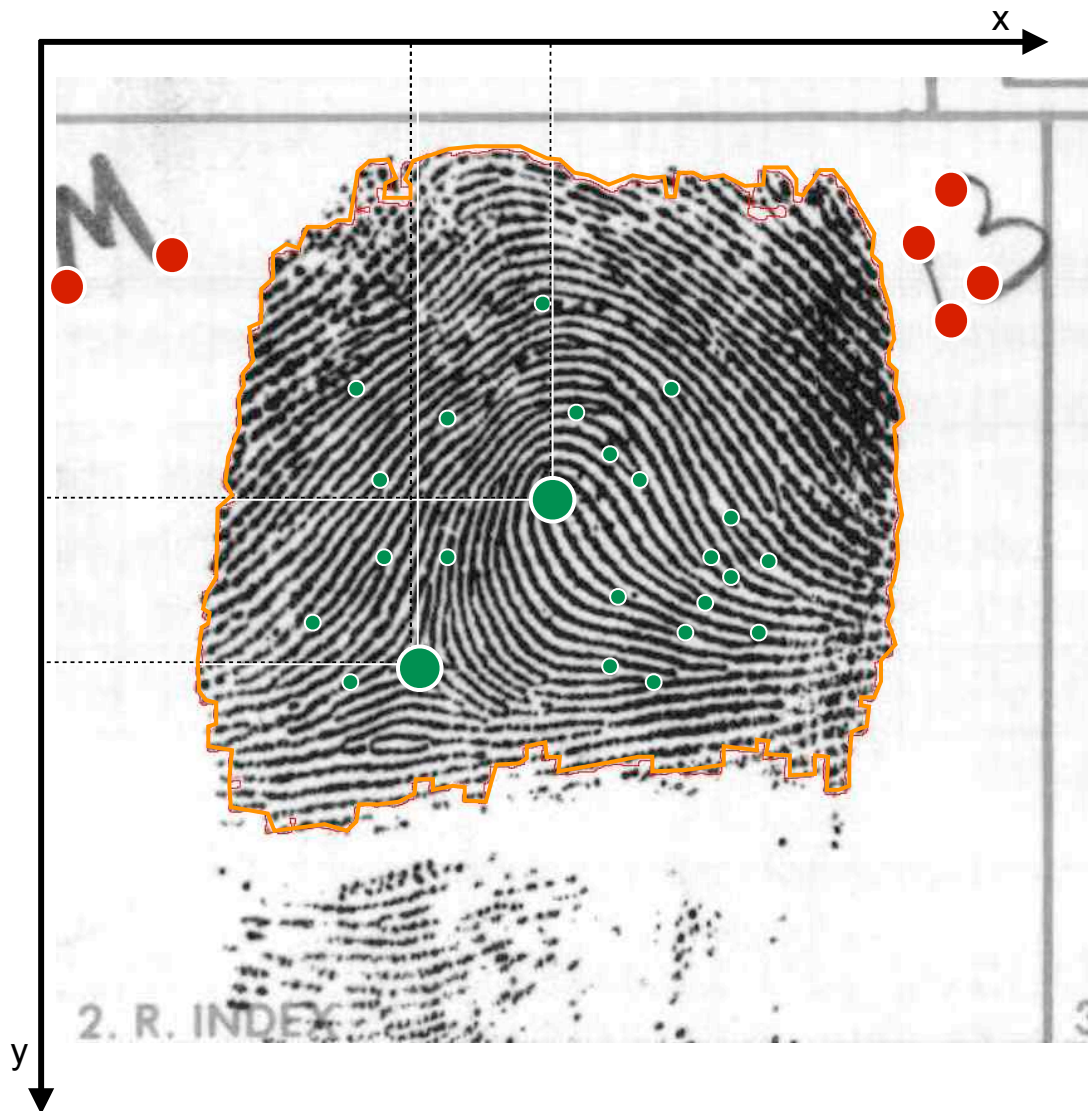
Unfortunately sometimes a feature extractor does not detect a landmark and thus relevant information is missing in the minutiae template. (sandstorm problem)

Deficiencies of the Minutia Encoder



In other cases a feature extractor fails to properly detect a landmark and thus encodes the feature at a dis-located position in the template. (fata morgana problem)

Deficiencies of the Minutia Encoder



Furthermore some feature extractor does not concentrate to the region of interest and thus detect spurious minutiae out of area or at the border of the imprint (globalisation problem)

Conformance Testing Methodology of Finger Minutiae Detectors

Conformance Testing

Conformance testing is defined in a dedicated standard, which is currently under development

- ▶ ISO/IEC IS 29109-1 Information technology — Conformance testing methodology for biometric data interchange formats defined in ISO/IEC 19794 — Part 1: Generalized conformance testing methodology
- ▶ ISO/IEC FDIS 29109-2 Information technology — Conformance testing methodology for biometric data interchange formats defined in ISO/IEC 19794 - Part 2: Finger minutiae data
- ▶ ISO/IEC 29109-1 formulates the relevant test type „A“:
 - attesting that a unit is **generating** conformant biometric data interchange records.
 - in the case of fingerprint data this tests will verify that a unit (e.g. a minutia extraction algorithm) can create finger minutiae data records (templates) from appropriate fingerprint image data.

Level of Conformance Testing

There are various level of conformance tests:

- Level 1 Basic Data Field Testing:
 - ▶ all **data** fields **exist** properly (e.g.in the correct encoding.)
- Level 2 Internal Consistency Testing:
 - ▶ all **data** fields are filled with **meaningful values** and the fields are internally consistent.
- Level 3 Semantic Testing:
 - ▶ a semantic test to verify that a generated biometric data interchange record is a **faithful representation** of the initial digital representation.

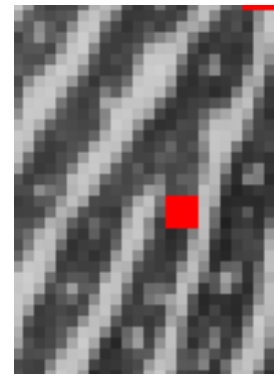
Semantic Conformance Testing

For fingerprint minutiae data

- template consists of **automatically** generated minutiae (*agm*)
 - ▶ *agm*'s are encoded by an implementation under test (IUT)
- semantic test to be covered by ISO/IEC 29109-2 AMD1
- semantic conformance is assessed by three rates:
 - ▶ 1.) Test for the **sandstorm** and the **fata morgana** problem:
 - Is there for every ground truth minutia (*gtm*) in the vicinity an automatically generated minutia (*agm*) in the template?
 - ▶ 2.) Test for the **out-of-area** problem (false minutia):
 - How many automatically generated minutiae (*agm*) are placed outside or at the border of a fingerprint area?
 - ▶ 3.) Test for **spurious** minutiae in the fingerprint area:
 - How many automatically generated minutiae (*agm*) do not have a mate in the gtm-set

Proposed Testing Methodology

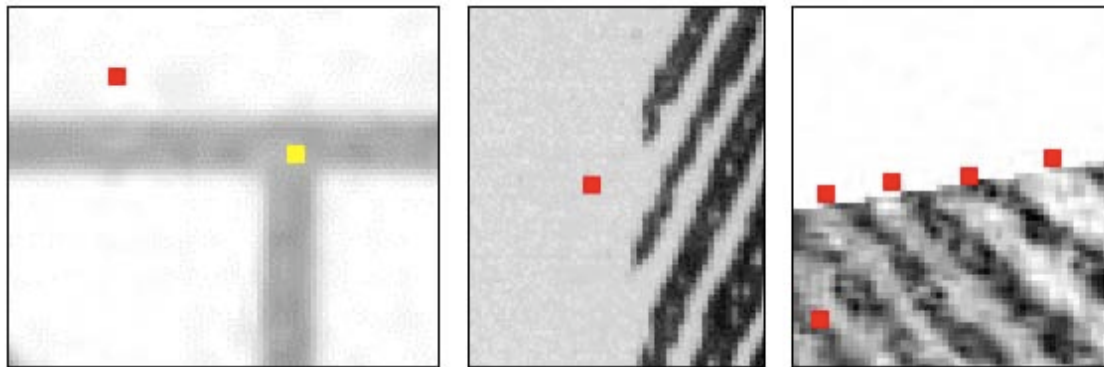
- Sandstorm and fata morgana *gtm*-test:
 - ▶ The gt-minutiae assertion test yields a **first** conformance rate cr_{gtm}
 - indicating the proportion of elements in the set of gt-minutiae for which a **corresponding** minutia **exists** in the set of automatically generated minutiae,
 - such that values can be compared for each data field and differences can be measured.
 - the assertion requires the corresponding minutia to be in the **vicinity**.



bifurcation detected
dislocated as ridge ending

Proposed Testing Methodology

- **Out-of-area** *agm*-test assertion:
 - ▶ assesses the number of outside false minutiae (false minutiae)
 - ▶ an out-of-area *agm*-minutiae assertion test is yielding a **second** conformance rate cr_{agm} that is indicating the proportion of elements in the set of *agm* that are inside or at the borderline of the fingerprint area.



Proposed Testing Methodology

- **Out-of-area** *agm*-test assertion:

- ▶ **second** conformance rate cr_{agm}

$$cr_{agm} = \frac{\sum_{i=1}^{n_{agm}} mps_i}{n_{agm}}$$

- ▶ where n_{agm} is the number of elements in the *agm* set and mps_i is the minutia position score for the i -th ag-minutia that indicates the homogenous distribution of ag-minutia with respect to the fingerprint area.
- ▶ metric will reflect a "punishment" for those *agm* that are on the borderline or outside the fingerprint area according

$$mps = \begin{cases} 0 & \text{if } agm \text{ is outside the fingerprint area} \\ 0,5 & \text{if } agm \text{ is at the borderline} \\ 1 & \text{otherwise} \end{cases}$$

Proposed Testing Methodology

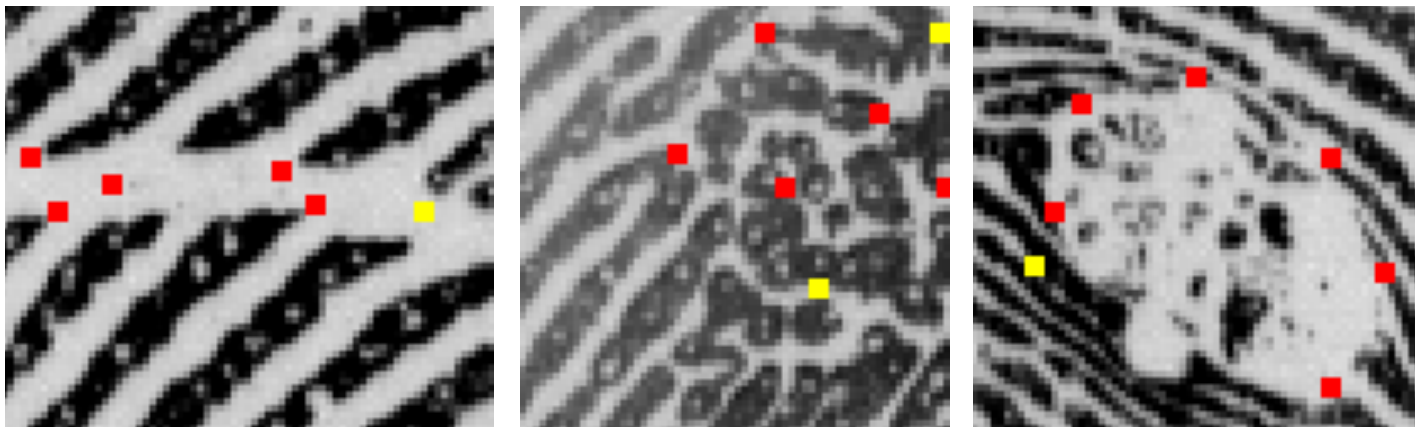
- **Spurious** *agm*-test assertion:

- ▶ The set of *agm* minutiae may contain **spurious** minutiae that are located **in** the fingerprint area
 - scars, bent skin, skin disease, dirt, etc.

- ▶ **third** conformance rate cr_{amf}

$$cr_{amf} = 1 - \frac{niagm}{nagm}$$

- where *niagm* is the number of focused *agm* inside the fingerprint area, which does not correspond to any *gtm*.



Composing Ground Truth Fingerprint Minutiae Data

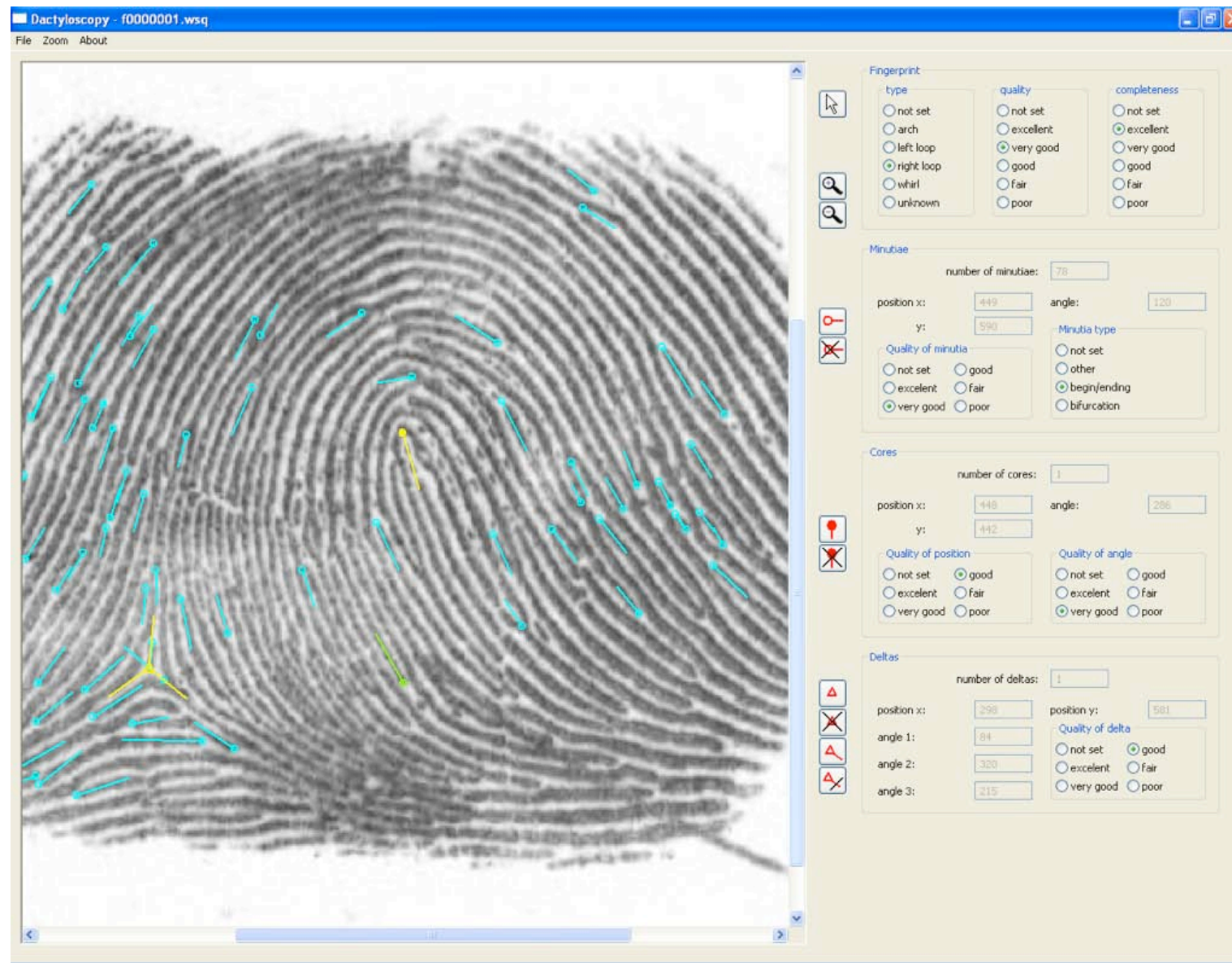
Semantic Conformance Testing

Challenge for implementing Semantic Testing:

- What is the „real minutia coordinate“?
- need for ground truth database (*gtd*) with minutiae data
 - ▶ **need** for public available fingerprint image **data** that is not restricted by privacy regulations
 - NIST special databases:
 - SD14 rolled data and mostly ink with few live scanned images
 - SD29 flat data /plain impression but all ink
 - ▶ **need** for dactyloscopic **experts** that define the truth!
 - Germany: Federal Criminal Police Office (BKA)
 - Australia: CrimeTrac
 - Czech Republic: Criminalistic institute Prague

Graphical User Interface

Ground Truth Minutia - GUI



Benefit of a Ground Truth Minutiae Database

Benefit of a Ground Truth Database

Database can serve for many purposes

- providing the ground for **development** of a semantic conformance test methodology
- providing the ground for semantic conformance **tests** according ISO 29109-2 AMD1
- providing the ground for development and calibration of fingerprint image sample quality metrics
 - ▶ NFIQ2-development and training
- providing the ground for dactyloscopic training software

Initial Test Results

Test Results

Results BIOSIG 2009

- 17 images, max 11 experts each
- average *ngtm*: 59
- average *agm*: 100 (for NIST mindtct)

conformance rates	Cr_{gtm}	Cr_{agm}	Cr_{amf}
average	0,353	0,885	0,662
std. deviation	0,179	0,066	0,178

Test Results

Results BioKeyS 2010

- 3 experts opinions each for 975 images (733 used)
 - ▶ SD14: 486 images / SD29: 247 images
- SD14 average *ngtm*: 76 (min 7 / max 174)
- SD14 average *agm*: 201 (min 87 / max 366) (NIST mindtct)

conformance rates	Cr_{gtm}	Cr_{agm}	Cr_{amf}
average	0,464	0,857	0,645
std. deviation	0,092	0,063	0,123

- Generating this result was kindly supported by the German BSI under the BioKeyS-Pilot-DB project

Conclusion

- Conformance testing essential step in system selection
- Semantic conformance testing requires ground truth data
- Further datalogic experts groups welcome
- Testing methodology under development
 - ▶ fusion of conformance rates
 - ▶ thresholds for the conformance rate
- Further data segments addressed soon

Further Information

on Semantic Conformance Testing

- On March 5, at 11:30 a session on fingerprint feature markup and testing will be held.
 - ▶ This workshop will discuss work in this area, interoperability, reference datasets, and the possibilities for semantic conformance testing.
- Publications:
 - ▶ C. Busch, D. Lodrova, E. Tabassi, W. Krodel: "Semantic Conformance Testing for Finger Minutiae Data", in Proceedings of the IEEE International Workshop on Security and Communication Networks (IWSCN), Trondheim, ISBN 978-82-997105-1-0, pages 17-23, (2009)
 - ▶ D. Lodrova, C. Busch, E. Tabassi, W. Krodel, M. Drahansky: „Semantic Conformance Testing Methodology for Finger Minutiae Data“, in Proceedings BIOSIG 2009, (2009)
- Website with information on the topic
 - ▶ <http://www.igd.fraunhofer.de/~busch/gtd>

Thank you for your attention
and many thanks
to the dactyloscopic experts
contributing to the
ground truth database

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